The effect of outdoor vegetation as seen from the dwelling's window on self-reported noise annoyance

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Summary
The effect of outdoor vegetation as seen from the window of the living room on the self-reported noise annoyance was studied. Face-to-face surveys were taken at 105 participants at their homes (in the city of Ghent, Belgium). The living room, facing the road, was in all cases directly and highly exposed to road traffic noise (Lden levels between 65 and 80 dBA as taken from the official END's road traffic city noise map). Although noise levels at the most exposed facade were high, the percentage of dwellers in this survey that were at least moderately annoyed by noise was rather low (19%). This can be partly explained by only selecting dwellings with a pronounced quiet side to rule out this effect. Visual outside vegetation from the living room was shown to have a strong effect on the remaining self-reported noise annoyance; the chance of being at least moderately annoyed by noise when view on outdoor vegetation is absent is about 5 times as high compared to having a pronounced green visual.

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1. Introduction

The human audio-visual interaction can be strong. Fastl [1] described a (controversial) experiment where the colour of the visual stimulus influenced loudness evaluation in such a way that - for the same acoustic stimulus - the loudness of a red train can be rated 15% higher than in case of a green train.

Aylor [2] concluded that as long as the source of sound can be seen, reduction in the visibility of the source is accompanied by a reduction in apparent loudness. However, when the source is completely obscured by a barrier, this effect reverses, i.e. the apparent loudness increases.

Other experiments focused on the mere presence of vegetation, and how this affects sound perception. Non-human sounds like road traffic noise were perceived as less unpleasant and less stressful when the visual setting was less "urban" or greener [3]. Gidlöf-Gunnarsson [4] showed that attractiveness of quiet sides is an important prerequisite to benefit from this effect. The presence of natural green is an obvious way to achieve such a pleasant non-directly exposed facade or courtyard.

Given the aforementioned reported experiments, exploring how the presence of vegetation can be exploited to improve environmental noise perception makes sense. In many urban situations, the range of solutions that could be applied is rather limited due to lack of space or due to the dominance of engine noise. Therefore, deliberately introducing vegetation could help complementing those traditional noise abatement solutions [5][6]. An important question is then whether this concept of visual green still works in case of highly noise exposed dwellers.

2. Ring road noise annoyance survey

The survey was taken along different sections of a busy city ring road in Ghent, Belgium. Following the European Environmental Noise Directive (END) noise map, this zone is highly noise exposed, with road traffic Lden levels ranging from 65 dBA to 80 dBA (see Fig. 1). The median Lden level at the front facade of the 105 selected dwellings was 73 dBA. The Lday levels in this zone were slightly lower than the Lden predictions with a rather constant offset of 1.6 dBA. Although often concerns are risen regarding the accuracy of such strategic noise maps, levels near busy roads at the front facade, as those considered in the current study, should be reasonably accurate.

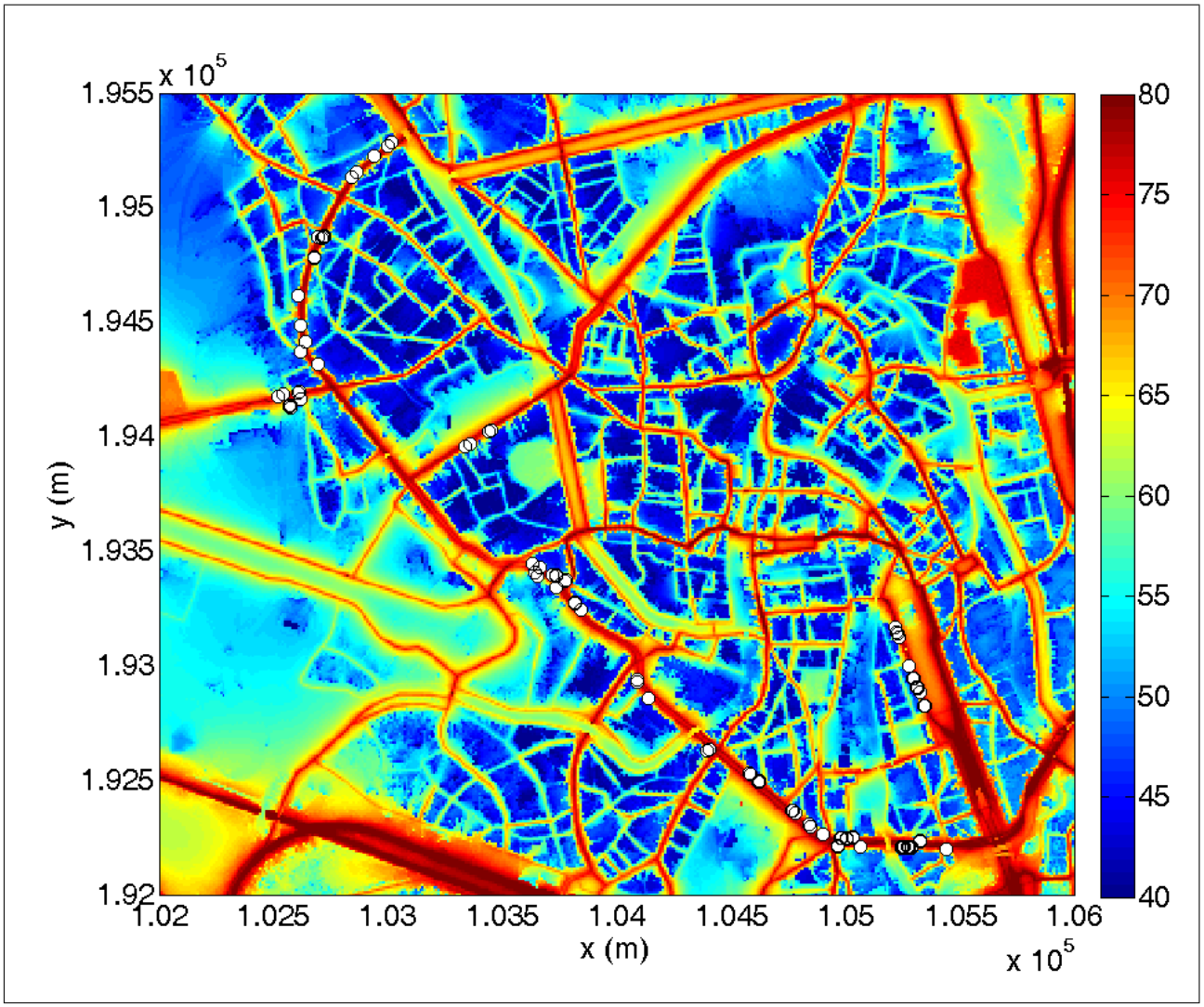

Figure 1. Officially approved environmental noise directive (END) road traffic noise exposure map with indication of the 105 survey points (white circles). The colormap presents the day-evening-night equivalent noise levels (Lden, in dBA).

Parts of this ring road are characterized by either an abundance of vegetation (street trees, parks bordering the road, etc.) or a complete lack of green, ensuring sufficient contrast in the dataset.

Only respondents living at least 1 year at the location were retained. It was ensured by the interviewer that each selected dwelling had a living room window facing the ring road. Face-to-face interviews were taken to ensure high-quality information. The surveys were taken during summer time, so when all trees were in leaf.

The ISO-standardized noise annoyance question was asked ("If you consider the past 12 months, to what degree were you annoyed or not annoyed") and respondents could answer employing a 5-point categorical scale ("not at all annoyed", "slightly annoyed", "moderately annoyed", "strongly annoyed", or "extremely annoyed"). The self-reported green visual through the living room window was assessed on a 5-point categorical scale ("extremely green", "very green", "moderately green", "some green" or "no green at all"). In the current study, it was enforced that all respondents have a pronounced quiet side. This was achieved by only selecting dwellings appearing in closed building rows. Research in different European countries [7][8][9] suggested a strong link between the presence of a quiet side at a dwelling and the self-reported noise annoyance and sleep disturbance. In the particular city under study, a previous survey [9] revealed a strong quiet side effect as well. By ensuring a quiet side at each participant, this effect has been ruled out and will not interfere with the effect of a green visual from the living room window.

		green visual	no green visual
front-façade L_{den}	L_{den} < 65 dBA	7	1
	65 dBA ≤ L_{den} < 75	27	28
	L_{den} ≥75 dBA	27	15
general neighborhood satisfaction	at least moderately satisfied	51	32
	"not" and "not at all" satisfied	10	12
general self-reported noise annoyance	"not at all" and "slightly" annoyed	56	29
	at least moderately annoyed	5	15

Figure 2. Selection of respondents' answers, categorized by the presence of a green visual (i.e. at least a moderately green view from the living room window towards the street as reported by the respondent) or "no green visual" (grouping self-reported "no green at all" and "some green").

3. Results

3.1. General analysis of the self-reported noise annoyance

Not unexpectedly, road traffic came out as the main environmental noise annoyance source at the dwellings where the survey was taken since locations were deliberately looked for where the END road traffic noise map predicted high levels.

The general noise annoyance question revealed that 53% of the respondents are not annoyed, 47% are at least slightly annoyed, 19% are at least moderately annoyed, and 8% are at least highly annoyed. Given the high most-exposed facade noise levels, these are rather low values, and can possibly be explained by the presence of a distinct quiet side near each dwelling. Other types of traffic noise annoyance sources (so other than road traffic) were nearly absent.

The survey showed that the self-reported noise annoyance is strongly linked with the general (self-reported) living quality in the neighborhood. Dwellers annoyed by noise advice friends or relatives to come live in their neighborhood to a much lesser extent. Street littering has a rather similar impact on the neighborhood satisfaction, while odor annoyance has a slightly stronger negative impact.

3.2. Effect of visual outside green on self-reported noise annoyance

A selection of the respondents' answers, categorized in either a "green visual" or "no green visual" is shown in Fig. 2. Logistic regression showed that visual outside green from the living room window is a statistically significant predictor of the noise annoyance in the current zone. Noise annoyance has been recoded to a dichotomous variable ("at least moderately annoyed" versus "not at all" and "slightly" annoyed). The self-reported green visual from the living room window has been recoded to a dichotomous variable as well ("at least moderately green" versus "some green" and "no green at all").

An odds-ratio of 5.8 between these dichotomous variables was calculated (with 95% confidence intervals on the odds-ratio extending from 1.9 to 17.5), meaning that dwellers that have at least a moderately green view are more than 5 times less (at least moderately) annoyed by noise than those that see at maximum some green by their living room window. The dependency between dichotomous noise annoyance and green visual is strong ($\chi^2 = 11.1, p = 9E-4$).

Although the front facade exposure, following the noise map that was used, is high at all survey locations, a green visual could strongly reduce self-reported annoyance to an acceptable level. It has to be stressed that all dwellings were selected to have a pronounced quiet side, a factor of importance as found in other studies, and in particular in the same region [9]. But even under these conditions, the view on green could further reduce environmental noise annoyance significantly.

4. Conclusions and discussion

Face-to-face interviews at 105 respondents, highly exposed to road traffic noise, showed that the self-reported greenness of the visual through the living

room window is a strong and statistically significant predictor of the self-reported noise annoyance. With increasing visible outdoor vegetation, respondents were less annoyed by environmental noise and road traffic noise in particular. The data suggests that visible outdoor green could be used in addition to ensuring a quiet side at dwellings to reduce noise annoyance along busy inner-city roads.

The current study was performed in cases of high acoustical facade load only. Combining the effect of visual green and a wide range of front level-facade noise levels would allow to calculate the equivalent sound pressure level reductions associated with a green visual (shift of dose-effect curves) to be applied more easily in e.g. noise action plan maps. However, the question remains if a simple (linear) shift would be a good approach. At the low end of the noise level range, the visual would most likely have no impact as little to no noise annoyance is expected there. The current study suggests that at the high end of the sound pressure level spectrum, green visual is interesting and leads to reduced noise annoyance.

The current study adds to the growing body of research showing the beneficial effect of urban green on noise perception in particular, and human health in general.

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